REPORT ON X-RAY CONSERVATION AND PRESERVATION TO THE FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION (FERMCO)

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EXECUTIVE SUMMARY

The Fernald Environmental Restoration Management Corporation (FERMCO) contracted with History Associates Incorporated (HAI) to provide support services for the Records Management and Medical Departments of the Fernald Environmental Management Project (Fernald). FERMCO asked HAI to examine and provide recommendations concerning the conservation and preservation of some 216,000 x-rays of former Fernald employees currently held at the Dayton Federal Records Center (FRC). This final report to FERMCO contains HAI's findings and these recommendations are based on the trip to the Dayton FRC and research performed in HAI's office.

HAI found the majority of the x-rays to be in a state of rapid deterioration. Many of the films are past the point of salvage, reduced to a collection of brittle emulsion and base chips and dust. Intellectual control over the collection is acceptable; FERMCO Records Management maintains a list of the employees whose x-rays are at the FRC and the x-ray storage folders are accurately marked. HAI's recommendations are based on the assumption that the x-rays cannot remain in the current state, and that action must be taken to save the images that are left.

This report explains the methodology used during the visit to the FRC and for the research conducted later, provides a discussion of the trip's findings, and furnishes FERMCO with several recommendations for the preservation and conservation of the radiographic images.

BACKGROUND

Site

The Feed Materials Production Center began operations in 1951 under the Atomic Energy Commission. Its mission was to process uranium metals and compounds for use in nuclear weapons. From 1951 to 1985, the site was managed by National Lead of Ohio (NLO). In 1986, the management contract went to Westinghouse Environmental Management Company of Ohio (WEMCO), which operated Fernald until 1992. FERMCO assumed the site's operations in December 1992, and manages the site today. Production levels were at their height in the late 1960s, followed by a slow decline in activities until the Reagan administration defense initiatives pushed levels up again. Production halted in 1989 and environmental clean-up began, and in 1991 the site was renamed the Fernald Environmental Management Project. In 1992, it became a field office under the Department of Energy's Office of Environmental Management.[1]

Medical X-rays

Medical Monitoring Program

Since 1951, Fernald employees have undergone health monitoring, required by Atomic Energy Commission and, later, Department of Energy directives. This monitoring occurred under the auspices of the Medical Department within the Health and Safety Division. The monitoring included annual physical examinations in which urinalyses, blood analyses, electrocardiograms, and chest x-rays were performed on each employee.[2] After 1981, only employees showing signs of chest diseases or those who requested them were given annual x-rays.[3]

Film Development

Until 1986, Fernald technologists developed the x-rays by hand, a process that was then ten to fifteen years out of date, but have since used an automatic processing system that reduces the potential for human error. Fernald has used a variety of film brands, including Eastman Kodak, DuPont, and Chronex, much of which is likely to have a cellulose acetate base. Over the last decade or so, Fernald has used Eastman Kodak, Marmer X-Ray Inc., and Picker International processing chemicals. The film and chemicals themselves do not appear to have created any substantial problems with deterioration other than those inherent in the instability of the medium itself.

Although the federal government currently has no nation-wide quality assurance regulations for the development of chest x-rays, the Fernald Environmental Management Project (FEMP) Medical Department Radiographic or X-ray Section has developed and maintains a Quality Assurance Program. This diagnostic x-ray facility has planned systematic activities that provide adequate confidence to produce consistently high-quality images with a minimum of exposure to the patients and medical arts personnel. Quality actions include quality control techniques and quality assurance procedures. The Food and Drug Administration (FDA) has an agreement with the US Department of Energy to implement the Presidential Directive titled *Radiation Protection Guidance to Federal Agencies for Diagnostic X-rays*. Bi-annually, the FEMP X-ray Section is subject to a two-day inspection by the FDA. The inspection includes a full day evaluation of the quality assurance program.

Interpretation

At the time each x-ray was taken, it was interpreted by a qualified radiologist, and the radiologist's written opinion was placed in each employee's permanent medical file. The x-rays themselves were stored separately. The written interpretation ensured that, even if the original x-ray were misplaced or somehow destroyed, the information contained on the film would not be lost. Generally speaking, it is not feasible to reinterpret an x-ray long after it was taken. X-ray film is at the optimum diagnostic quality possible immediately after it is processed. Natural darkening and degradation that occurs even a few days later can reduce the effectiveness of a reinterpretation, and only worsen after a significant passage of time. However, certain circumstances could warrant a reinterpretation. A physician might wish to examine an x-ray for qualities different from those sought during the original reading. For example, an image taken to examine bone structure could be re-examined for soft tissue anomalies if necessary. Using older x-rays to establish a foundation representation to which later films are compared may also be reason to reread a film. Additionally, if a physician has reason to suspect the bias or ability of the radiologist who originally read the film, he or she might wish to study it himself.[4]

X-ray Storage
Currently, 138 boxes, or approximately 216,000 individual x-rays in 7,200 folders are stored at the FRC in Dayton, Ohio. The films date from 1951 to 1988, and were transferred to the FRC in 1973, 1984, and 1989 by NLO and WEMCO. The x-rays are considered to be federal records, and are stored pursuant to AEC and DOE regulations once they are no longer actively needed.

The FRC has verbally requested that the DOE and FERMCO remove the x-rays from their present storage location in the FRC. Given the current state of severe deterioration and problematic vapors with the accompanying offensive odor, the FRC does not wish to continue to house the x-rays. FRC staff believe it would be negligent on the part of the FRC to continue to maintain records they know are deteriorating badly. The facility does not have the means of providing the proper environmental controls for the storage of x-rays, and as a result, the films are in a state of severe deterioration. The deterioration process emits vapors which have an offensive odor, and may pose a health hazard to persons working with and around the records, especially when the air circulation is poor and the vapors are permitted to concentrate.

FERMCO, however, informed HAI that waste management officials at Fernald may not be eager to have the x-rays returned to the site because of the additional regulatory activities they would generate. Silver and other compounds in the emulsions fall under Resource Conservation and Recovery Act (RCRA) disposal restrictions. If the x-rays are returned and ultimately destroyed, the site must follow the requirements set out in RCRA regulations to maintain the x-rays onsite and dispose of them properly.[5]

Litigation
In 1990, a class-action lawsuit was filed against the former managing and operating contractor, NLO, on behalf of current and former Fernald employees. The case was settled in 1994, and the current settlement agreement entitles former employees to lifetime medical monitoring. The medical monitoring physicians have requested to view the original x-ray films in an effort to establish baseline readings for each worker.

Retention
Employee medical x-rays are covered under the General Record Schedule (GRS) 1.21a(2), which requires that employee medical folders be retained for a period of 75 years beyond the person's date of birth, 30 years beyond the final separation date, or 60

years past the earliest document in the file if the birthdate cannot be determined, whichever is longer.[6] Approximately 850 employee files have met these retention requirements. The Code of Federal Regulations (CFR) 1228.154, which mandates that employee medical folders be transferred to the National Personnel Records Center in St. Louis, Missouri, does not apply to DOE contractor personnel records. The National Archives does not presently have any regulations requiring the storage of x-ray film under special conditions.

Retention Concerns

The lengthy retention periods required under the GRS cause difficulties for agencies due to the unstable nature of x-rays and the large number which must be maintained. X-ray film is a delicate medium, prone to deterioration under even the best storage situations. The film is comprised of two layers, a base support and an emulsion containing light-sensitive chemical compounds. The base can be composed of many materials, including glass and paper, but for x-rays is usually cellulose diacetate and triacetate film. The emulsion is customarily a gelatin comprised of several compounds and light-sensitive silver halides. If any one of the compounds is damaged or altered, the chemical equilibrium of the processed film comes undone.[7] The chemical reactions which cause film to deteriorate are autocatalytic; natural degradation reactions start and produce products which catalyze further deterioration and accelerate the reactions.

Environmental conditions may either slow or accelerate this process. The higher the temperature and relative humidity, the sooner the film begins degrading. Film begins deteriorating under office-environment conditions (70°F/50%RH) within 30 to 40 years, and is likely to be seriously degraded long before the 75 year period required for federal x-rays has been met. Stored under warehouse conditions (60°-85°F/outdoor RH), the deterioration could begin within 15 years. After the onset of degradation, film remaining in office or warehouse conditions will deteriorate rapidly in less than ten years.[8] A retention period of 75 years or longer is not feasible if x-rays are maintained under standard office or warehouse storage conditions, and, in this light, the DOE and the National Archives may wish to re-examine the current retention period. For instance, one method of retaining the information might be to recommend that only the chest x-rays from every other year be kept for an extended period of time, and that x-rays be destroyed after the employee is deceased. In this manner, the DOE and its sites retain control over enough images to allow for the documentation of irregularities without maintaining large numbers of film sheets. These images can be transferred to another medium, whether microform, optical or magnetic disc, copy negatives, slides, or some other format, to help prevent the type of severe deterioration that DOE and the sites must deal with now.

DOE Destruction Moratorium

In addition to the GRS directive to maintain personnel x-rays, the x-rays are currently subject to the DOE-mandated records destruction moratorium. In 1989, the Secretary of Energy placed a moratorium on the destruction of all records potentially needed to conduct epidemiologic studies that would otherwise be lost through normal records destruction. The moratorium was extended in 1994, to allow for the completion of epidemiologic records inventories at each site. Unless a site can prove that a records series does not have epidemiologic-study value, all potentially epidemiologic records must be retained, and the destruction of records that have otherwise legally met the required retention periods is prohibited for the foreseeable future.

METHODOLOGY

HAI staff traveled to the Dayton FRC in November 1995 to examine the Fernald x-rays currently stored there. They inspected random samples of the film for signs of deterioration, including "vinegar syndrome" odor; buckled and cracked emulsions, also known as channeling; bubbles or pockets in the emulsions; residue spots; and crumbling emulsions and bases. HAI interviewed FRC and FERMCO medical and records staff about the quantity and quality of the film and collected information regarding film processing and the problems FRC and FERMCO staff perceive with the x-rays as they are currently housed. On the second day of the trip HAI met at FERMCO's records management offices to discuss the x-rays, the class action lawsuit settlement, and other issues to be addressed in this report.

After the trip, HAI staff conducted research about x-rays and film standards. HAI consulted with representatives of Eastman Kodak, Sinai Hospital in Baltimore, Maryland, Jansen Image Information Management Company, B&B Information and Image Management Company, the Association for Information and Image Management, DOE, and the National Archives and Records Administration, regarding image transfer alternatives, legal considerations, health hazards of deteriorating film, and image-quality specifications.

FINDINGS

Physical Condition

Fernald's x-rays are currently stored in a classified records vault at the FRC due to the severity of the "vinegar syndrome" odors. While the x-rays are not classified, the vault offers the FRC staff more protection against the strong odors than storage in the general stack area. The conditions of the x-rays located at the FRC range from good to completely disintegrated and irretrievable. "Good" x-rays are in adequate visual condition but have started to exhibit "vinegar syndrome" off-gassing. "Vinegar syndrome" is the common name for the emission of acetic acid vapors from film due to the production of the acid in normal chemical decomposition reactions in the cellulose acetate base. While some fumes escape into the air, a portion of the gas remains in the envelope and box enclosures and thereby accelerates the deterioration process. Disintegration has started in these x-rays, but could be slowed somewhat with the proper environmental controls.

The images are readable, and would likely transfer to another medium without too much resolution loss. Film sheets in deteriorated but salvageable condition show signs of channeling and bubbling emulsions in addition to the vinegar syndrome, and may have an eroded image. These images may or may not transfer well; much depends on the location and severity of the channels, bubbles, and other blemishes. Handling x-rays in this condition exacerbates the deterioration processes and may also cause the loss of emulsion or base. A significant portion of the film, however, is brittle and crumbling past the point of retrievability. These films cannot be handled without losing pieces of the emulsion and base, while channeling and other blemishes have obscured the image beyond readability. These x-rays must be written-off as losses.

Today, x-ray film is developed by an automatic processor which moves the film from bath to bath and keeps the chemicals properly mixed. This cuts back significantly on the potential for poorly processed x-rays. Until 1986, Fernald developed film using hand tanks and processed the film by hand. Individuals performing and processing the x-rays were not always x-ray technologists and as a result, the x-rays were inconsistently processed and washed. This has led to x-rays with chemical residues, accelerated deterioration, and poorly developed images. In addition, the inconsistent processing quality has made it impossible to accurately predict a cut-off date before which the x-rays are invariably badly deteriorated.

Storage

The x-rays are currently stored in paper and manila envelopes, as many as thirty or forty to a sleeve, laid flat in cardboard boxes. Each envelope contains films in all conditions. An envelope may hold x-rays from 1951 to 1988 that run the gamut from good to completely disintegrated. A well-processed 1950s film may be in reasonable condition while a poorly handled 1980s x-ray is already exhibiting signs of deterioration. A good x-ray may be next to one that is crumbling or emitting strong acetic acid gases. The x-rays are directly touching because no interleaving papers separate the film sheets. The acetic acid vapors, fixing bath residues, and other chemical compounds involved in the rapid deterioration of the poor x-rays migrate from film to film and combine in the enclosed atmosphere of the containers, thereby affecting the degradation processes of the better and newer x-rays in the same enclosures.

The boxes in which the x-ray folders are stored are located on the highest shelves in a thirty-foot-high vault directly beneath the fluorescent light source. The heat from the light source adds to the temperature fluctuations in the immediate area, and ultraviolet radiation from the fluorescent bulbs also accelerates the deterioration. The vault itself is not well ventilated, but staff members are in and out of the area several times during the day, thus providing some air circulation in the vault, which helps cut back on the build-up of the acetic-acid vapors in the room. For a period of time in the late 1970s and early 1980s, the storage area had minimal air-conditioning to stabilize the environment. Budget cutbacks in 1986 eliminated even this nominal control, and the film has since been subjected to warehouse conditions, including temperature fluctuations between 60°F and

85°F and humidity levels similar to those outdoors. HAI and FERMCO staff observed x-rays from other government facilities in the vault with the Fernald x-rays.

Retrieval

The front of each folder is labeled with information about the contents. It lists the employee's name and the date and image of each x-ray in the file. The information is considered to be accurate. To facilitate retrieval, FERMCO records personnel maintain lists which indicate which employees' x-rays are stored in a particular box. The physical handling required for an x-ray to be removed from the FRC and sent to FERMCO is extremely detrimental to the life of the film. The physical stress which film sheets undergo during retrieval, transfer to and from the site, and copying causes irreparable image loss. The emulsion and base crack and flake off; the air pollutants to which a film is exposed during the transfer accelerate the chemical reactions; airborne particles abrade the image; and the oils and other impurities on the hands of those who move the film contribute to overall deterioration. Nearby x-rays are also damaged due to the friction of removing an x-ray from its folder, and through the simple actions of lifting the storage box off a shelf or moving other folders to reach the appropriate employee's file.

Health Hazards

X-ray films emitting acetic acid gas pose a potential health problem for staff who are exposed to the gas for significant amounts of time. In its pure state, acetic acid is considered to be moderately toxic when ingested or inhaled, and is also considered a moderate fire hazard. Occupational Safety and Health Administration guidelines require that the Threshold Limit Value (TLV) for acetic acid in the workplace atmosphere be no more than ten parts per million. The TLV is a measure of the concentration of airborne substances in workplace air to which workers can be exposed on a repeated basis without adverse health effects.[9] Therefore, poorly ventilated areas where the gas can build up pose a serious health hazard, and should be entered cautiously. In addition, HAI observed individual x-rays that were nothing more than flakes and dust. Inhaling these particles, which contain silver halide dust, acetic acid, and other chemical compounds, can pose health problems for people prone to respiratory difficulties. In addition, silver is a moderately heavy metal that, once in the body, is not always easily voided. HAI recommends that persons handling the x-rays for extended periods of time wear gloves, goggles, and respirators fitted with acid/organic vapor filters. Persons working in poorly ventilated storage areas containing the x-rays should wear respirators and goggles.[10]

Other Sites

During work HAI performed for the Office of Epidemiologic Studies (EH-62), HAI observed medical x-rays for other DOE facilities stored in the regional FRCs, under physical and environmental conditions similar to Fernald's. HAI observed these x-rays to be cracked, brittle, emitting off-gases, and in a state of disintegration similar to those of Fernald x-rays. DOE Records Management has indicated to HAI that sites throughout the DOE complex are faced with coping with x-rays in much the same condition.[11]

OPTIONS

Due to the present condition of the majority of the x-rays and the requirements necessitating the retention of the images, it is apparent that action must be taken to preserve those images that have not yet completely deteriorated. Some volume reduction is possible simply because the x-rays have deteriorated into nothingness, although these films must be documented in some fashion. DOE might want to consider that only every fifth chest x-ray be kept along with the entrance and exit films. If that were the case, and an employee worked from 1960 to 1981 (the last year annual chest x-rays were required), 22 x-rays would be reduced to six. Approximately 173,300 total x-rays could be eliminated. Destroying the x-rays of all employees whose films have currently met retention requirements is another option, would reduce the volume by 850 files, roughly 25,500 x-rays. These alternatives work only if FERMCO can obtain permission from DOE to have the epidemiologic records destruction freeze lifted for those x-rays, which may or not be possible.

HAI has provided FERMCO with five options regarding the preservation of Fernald's x-rays at the Dayton FRC. The options are emulsion transfer, digitization, microfilming, slide duplication, and cold storage. A table summarizing the options, costs, and advantages and disadvantages follows the narrative explanations.

1. Transfer of Emulsion

In some cases, the emulsion on a sheet of film is not as badly damaged as the base on which it rests. In these instances the Image Permanence Institute suggests that it may be possible to remove the emulsion from the base. The emulsion can then be flattened and straightened and either photographed or transferred onto a new base. This process involves the use of hazardous solvents and requires painstaking attention to detail. If problems arise during the process, the image could be irretrievably lost or damaged. Costs for this type of restoration are prohibitively high.[12] HAI has been unable to determine any organizations that carry out this type of restoration work, however. Given the large number of Fernald x-rays and the severely disintegrated condition many are in, this option is not feasible for the collection as a whole. This option should be considered only in extreme circumstances, e.g., where the damaged x-ray is determined to be crucial for an employee undergoing medical monitoring who develops a health problem.

2. Digitization

Technological advances in recent years have made it possible to scan and then digitize any number of documents and images and transfer that information to optical media. This option offers some real advantages and disadvantages to FERMCO, but is also one of the costliest alternatives. In the digitizing process, images are bitmapped, that is, they are documented dot by dot to record every inch of a document. Most textual documents are digitized at a resolution level of 200-300 dots per inch (dpi). This level may not be sufficient to record all of the nuances and shadings of grey in a radiographic image. An x-ray is going to require a much greater resolution level than a textual document, perhaps as much as 400 dpi, and is also going to require a display system capable of displaying all of the shadings of grey (12-bit, 4096 Grayscale). These display requirements, along with the large size of the images, dictate the amount of storage an image will take up on an optical disc or in a computer system, which contributes to the overall cost of this option.

If image-manipulation is performed on the images after they have been scanned, it may be possible to improve the readability of some x-rays that would not be comprehendible if they were transferred to microfilm or slide when the image cannot be cleaned-up. It is possible that the clarity will improve to the extent that, when cracks, bubbles, and darkening are removed, aspects of the image not readily visible on film could be seen.[13] In addition, digitized images can be enlarged and rotated to provide the physician with a better view of a portion of the image than is possible using the original x-rays, microfilm, or slides.

Estimated costs for scanning and digitizing the x-rays are:

Image Pro software required for viewing images:	$2,995.00
Basic indexing included, customized per hour is:	125.00
Prescanning film preparation labor costs per hour:	35.00
Other labor costs (image restoration work, editing, image clean-up, re-scaling, etc), per hour:	35.00
Scanning at 12-Bit, 300 dpi, (4200 x 5100 pixels), 4096 Grayscale with unattended static threshold batch processing per 1,000 images:	2,310.00
Scanning at 12-Bit, 300 dpi, (4200 x 5100 pixels), 4096 Grayscale with attended quality control for each film per 1,000 images:	3,500.00
CD-ROM Production, each	100.00
Duplicate CDs, each	50.00

B&B provided these estimates to HAI based on a volume of 100,000 images or more, with the understanding that a representative sampling of the films would be processed, at no cost, and the results accepted by the client before scanning the remaining images. The cost estimates also assume that the hardware required for the system is already available to FERMCO. Costs for lower resolution images [the lowest B&B suggests is 8-Bit, 150 dpi (2100 x 2550 pixels), 256 Grayscale] start at $1.225 each for unattended scanning, or $1.85 each for attended scanning. Prices may vary depending upon who receives the price of the recovered silver.

A primary drawback to this option involves the subjective judgement of the persons doing the scanning. They will be the ones responsible for deciding when an x-ray is too cracked, bubbled, darkened, or otherwise damaged to warrant scanning. This could pose problems unless the contract lays out specific parameters under which the images will be scanned. Additionally, B&B's option makes no arrangements for documenting images that are too damaged to scan, and thereby visually certify that these images did exist. The index database to the CD-ROMs must, however, include some form of documentation that these images could not be scanned.

HAI recommends that a master set of the CD-ROMs be maintained and working sets be created for normal use and copying. This provides a back-up in case of disk damage or crashes, and would be the set used for technology upgrades.

Due to the legal sensitivity of these images, and because this technology does provide opportunity for the images to possibly be manipulated or altered, HAI suggests that legal counsel concurs with this form of image transfer and be involved in determining the extent to which images may be enhanced for clarity.

FERMCO staff may wish to speak to personnel in the Clinical Investigations Branch of the National Institute for Occupational Safety and Health. The branch is currently leading an initiative to explore the feasibility of converting coal miner x-rays to optical systems.[14]

3. Microfilming

Microfilming is one of the best options available to FERMCO. Microfilming transfers the images to a more stable film format while retaining the needed information. The film is more compact than the x-rays, and therefore easier to store. On properly indexed film, the images can be quickly retrieved, and can be copied as needed. Done correctly, the images can be filmed so they are oriented for a physician's use. Proper backlighting adjusted for each x-ray helps ensure that each image is filmed at the best possible clarity.

Microfilm should include the standard test frames, density grids, and the like, as well as shots of each film jacket. Targets should be developed to be used in place of films that are too deteriorated to be filmed so that a documented record of every image is available on the film reel. This provides legal protection for the x-ray creators, as well as a complete record of each x-ray made. As with CD-ROMs, the master film negatives and a master copy should be stored separately from the working copies, along with copies in various formats of the index. Microfilm should be examined every year for signs of deterioration, and the images copied onto fresh film approximately every ten years.

HAI spoke with Jansen Image Information Management Company (JIIMCO) of Cincinnati, Ohio about this option. JIIMCO quoted filming costs of approximately $.05 to $.25 per x-ray, depending on the techniques used and who receives the price of the recovered silver. This averages out to $50.00 to $250.00 per 1,000 x-rays. This cost estimate includes packing and picking up the x-rays at the FRC, doing all preparation work, correcting misfiles, filming the images, conducting quality control, and destroying the originals. If FERMCO were to receive the price of the recovered silver, it could receive it in the form of cash, silver bars, or a credit toward the total bill.

If JIIMCO retains the silver, it provided HAI with the following cost estimate:

Filming of all x-rays (or targets for disintegrated films), including individual quality control during filming; 1,000 x-rays @ $.12 per x-ray:	$ 120.00
Basic indexing of two fields per record; 1,000 records @ $.25 per record:	250.00
Additional data fields:	.05 each
FoxPro retrieval software:	1,800.00
Image certification, per hour	120.00
Storage of originals (if required), @ $.27 per cubic foot per month:	40.00

JIIMCO will customize the FoxPro software to meet the client's needs, and will also microfilm a hardcopy of the index and provide a bound copy as back-ups to the computerized version.

If FERMCO requests it, prior to destruction, JIIMCO can work with an outside registered records technician who will view the film and the originals to certify that the microfilm contains the best possible images. HAI suggests that FERMCO seriously consider this service since quality and reliability of the images is of paramount importance.

Should it be necessary, JIIMCO can store the originals until they can be destroyed at a cost of $.27 per cubic foot per month. This averages out to approximately $40.00 per month for the 138 containers currently in the Dayton FRC.

Microfilming is certainly cost-effective for FERMCO considering the large quantity of x-rays which need to be handled, and is a proven method of preserving images in another format without image loss. Nor is it likely to undergo substantial technological change in the near future or require substantial technology upgrades. Unlike digitizing, however, the images cannot be enhanced or cleaned-up to eliminate the channels and bubbles that mar the image. Nor does microfilm offer the ability to enlarge and enhance portions of the image as a digitized image does. From a medical standpoint, this may need to be a consideration for FERMCO.

4. 35mm Slide Duplication

During conversations with medical film specialists at Eastman Kodak, HAI discussed a process of copying x-rays using 35 millimeter (mm) film. In this process, x-rays are placed on a lighted viewbox with a 35mm camera on a stable angle tripod in front or overhead. Photographs of the images are taken on Kodak's rapid-process duplicating film, and slides of each image are produced. The slides can then be copied or enlarged as needed. Although Kodak does not do this type of work, they make the proper materials available, and seemed to think that a project such as this one could be accomplished in-house.[15]

Estimated costs are:

Film and processing; @ 99.70 per 150 ft. film roll containing 1,200 exposures, per 1,000 x-rays:	$650-750.00
35mm camera:	200-350.00
Tripod:	100.00
Lightbox:	450.00
Slide cabinet for storage consisting of a base, two four-drawer units, top surface, and drawer dividers:	1,120.00

Labor costs will need to be added to the above figures. FERMCO should calculate these based on their own labor rates, but a rough estimate is $35.00 per hour.

Slides offer several advantages; like microfilm, they require less space and more reasonable environmental controls than the original x-rays. Slides can be enlarged and copied as necessary, and do not require users to scroll through microfilm reels looking for the desired image. In-house filming means that FERMCO could have more control over the technical qualifications of the people doing the filming and use staff knowledgeable about x-rays, if not x-ray technologists. However, unlike microfilm, staff conducting the photography sessions would still be required to use their own judgement regarding which x-rays are in a condition to be photographed. Neither do slides offer the security of visually documenting that some x-rays are beyond image transfer as microfilm does. Unlike digital images, and to a certain extent microfilm, slide images cannot be manipulated to develop the best possible image for a physician to view. In-house processing also raises the issue of waste disposal. Since FERMCO waste management has voiced concerns about having the added responsibilities of destroying the x-rays according to RCRA guidelines, in-house slide production is not a truly feasible option.

5. Cold Storage

Another option that is available involves transferring the x-rays to a proper storage environment and placing them in archival-quality enclosures. Cold storage with reduced relative humidity can extend the lifespan of deteriorating film remarkably. At 30°F/50% RH the lifespan increases by almost 110 years. At 20%RH, the film could last another 540 years. These figures, however, are guidelines that apply only to film caught in the very early stages of deterioration, which is a small percentage of Fernald's entire collection. The x-rays could not, however, be left in their current enclosures. The x-rays would need to be individually sleeved in acid-free, buffered envelopes. The envelopes should be kept vertically on special x-ray shelving or vertically in acid-free boxes. These storage efforts will slow the deterioration process by shielding each x-ray from the chemical reactions occurring in the other x-rays, and by slowing the reactions with the cold and low humidity. By storing the films vertically, the stress of the weight of x-rays' stored on top of one another is alleviated, and individual images can be removed from storage without disturbing the nearby x-rays. It is, however, extremely expensive to bring an area under the type of tight environmental controls needed to significantly extend the life span of these x-rays. A room large enough to hold 15 shelving units with the minimum amount of space between the shelves would have to be roughly 24' x 21'. The environmental controls needed to keep the conditions at 30°F/50%RH with only a two degree temperature variation and 5 percent humidity fluctuation permissible would be exceedingly expensive.

Cost estimates for transferring the x-rays to cold storage (24' x 21') include:

10" x 13" acid-free envelopes, per 1,000:	$ 280.00
Storage shelving (15 units):	1,750.00
Environmental System (includes HVAC, air filtration, fire suppression sprinkler system, UV filters for fluorescent light sources)	
Remodeled:	54,500.00
New:	100,000.00

These estimates, however, do not include the yearly cost of maintaining such a system.

The primary disadvantage to this option is, of course, that the x-rays will continue to deteriorate. Although better storage conditions will slow the chemical degradation processes, nothing can stop them once they have begun. Most of Fernald's x-rays are past the early stages of deterioration when better environmental controls could be a significant help. The x-rays in poorest condition would still not last long enough to satisfy the legal requirements of the GRS, the legal settlement, or the DOE destruction moratorium. Nor does cold storage do anything to prevent the degradation that occurs whenever the films must be handled for copying or viewing by the physicians. In addition, staff members who must work with the x-rays will still be exposed to the acetic acid vapors. And, as with in-house slide production, site waste management must cope with the added burden of maintaining and ultimately destroying the x-rays after legal retention requirements have been satisfied.

OPTIONS TABLE

Option	Cost Estimate (total collection)	Advantages	Disadvantages
1. Emulsion Transfer	Prohibitive	• Saves x-rays when emulsion is alright but base is deteriorated • Only for extreme circumstances	• Entire collection too deteriorated to attempt • Extremely costly • Emulsion may still deteriorate
2. Digitizing	$4.6 million to $7 million plus any specialized labor @ $35/hour	• Stable format • Image editing to clean up blemishes • Easy retrieval, copying • Enlargement, rotation of image for better view of sections • Indexing • Less space required	• Costly • Potential legal sensitivity requires care • Some subjective judgement of scanner • No arrangements to document fragmented x-rays
3. Microfilming	$80,000-$100,000 for basics only and if silver price goes to JIIMCO	• Stable format • Less space required • Quick retrieval, copying • All x-rays filmed • Visual record of fragmented x-rays • Indexing • Oriented for physician viewing • JIIMCO staff experienced w/x-ray filming • Contractor destroys originals • Cost-effective	• No image editing/clean-up • Enlargement & enhancement of sections difficult to impossible

4. 35mm Duplication	$80-90,000 plus labor, estimated at $35.00/hour (doesn't include indexing time, software)	• In-house work offers more control to FERMCO • Less space required • Easily copied, enlarged	• Subjective judgement calls by staff • Cannot clean up or edit • Site must destroy originals
5. Cold Storage	$117-165,000 (without yearly operating costs for env. controls)	• Enhances life-span of x-rays in early deterioration • Low-tech option	• Costly env. controls • Space requirements • X-rays continue to deteriorate • Poorer images may still not survive retention periods • Continued damage from handling • Staff health concerns • Site must store & destroy originals

RECOMMENDATIONS AND SPECIFICATIONS

Recommendations

HAI recommends that FERMCO either transfer the salvageable x-ray images to microfilm or digitize them and save them on CD-ROM. Both options convert the images onto a more stable format that offers quick retrieval and image copying in less space and under far fewer environmental and health restrictions. Both CDs and microfilm can be stored under office conditions for years without any significant deterioration. FERMCO should remember, however, that both CDs and microfilm will likely need to be copied during their lifetime to accommodate technological changes and to keep the film fresh.

The polyester-based film used today for microfilm does not deteriorate at the same rate at which acetate-based film does, and is considered to be more stable. In addition, it does not give off acetic acid vapors during deterioration, and therefore is not a health hazard to staff members who must work with it. Filming documents the existence of each x-ray, even those which have degenerated into chips and dust, as CD-ROM may not. It is cost-effective, given the large number of x-rays that require transfer, and provides adequate indexing and retrievability. However, the images cannot be manipulated for clarity as they can on a CD, so some obscured x-rays that could become usable again after digital editing and clean-up, might not be readable on microfilm.

CD-ROMs offer the possibility of clear, high resolution images and easily retrievable and printable replicas. Digitized images can be "cleaned" to eliminate signs of deterioration such as channeling, bubbles, and darkening. In addition, a physician can manipulate the view to enlarge and enhance specific portions of an image for a better reading. This manipulability, however, could conceivably cause legal concerns since digitization has not been standard business practice for x-ray preservation at Fernald prior to this time. Costs are also a major consideration, due to the large number of x-rays that must be copied. X-rays digitized at high resolution with individual quality control cost up to $3.00 more per x-ray to handle.

RFP Development

HAI suggests two methods of developing a Request for Proposal (RFP) to pick a technology and contractor which provides the best images possible for FERMCO's records and legal needs.

One method is a test of the most likely technologies. Two or three small RFPs could be issued to test the technologies on small, representative samples of the x-rays. In this manner, FERMCO could determine which technology will best suit their needs and the condition of the x-rays. FERMCO would also then be in a position to better define the specifications and requirements needed to obtain a quality final product. At that point, a final RFP could be issued for the entire collection.

Another possible option is to issue a phased RFP. After choosing the technology, for instance microfilm, FERMCO could issue an RFP consisting of two phases. Phase one would consist of a test of the technology. A representative sampling of the x-rays would be processed to determine the proper specifications and quality controls, and arrange for any necessary special considerations. Once the final product quality has been agreed upon, the rest of the collection would be processed according to those specifications. In fact, B&B Image and Information Management Company has indicated a willingness to work in this manner.

Specifications

Prevailing specifications for fresh x-ray images require that there be a density rate of approximately 2.0 in the upper-left hand portion of the left lung in a chest x-ray. Overall lung detail should be even, showing the heart outline, the bronchial tree, and all bony structures clearly, and both lungs should be entirely visible. While this density rate and structure clarity will not be possible with channeled emulsions, detail levels should be as close as possible to these if a transferred image is to be reliably interpreted.

FERMCO staff should keep in mind when making technology decisions that images which were in poor visual condition at the start of the transfer process may not transfer well enough to obtain a usable, clear image. To ensure that the images are transferred at the best possible clarity, HAI recommends that a technologist knowledgeable about x-rays be present during filming or scanning activities, or examine the final product against the original film to ensure a quality image. If an x-ray does prove too damaged to film or scan, a target should take its place to indicate that the deteriorated image is too damaged to be transferred, and the x-ray should also be documented in the image index.

At this time, no specifications have been developed for transferred images to ensure that images transferred to microform, other film, or computer system remain legible. The Code of Federal Regulations 21 (CFR) 892 and 1020 both discuss radiographic film, but only as it correlates to equipment standards and personnel certification. However, 36 (CFR) 1320.14 discusses microfilm processing standards, including density rates and residue concentration levels. The American National Standards Institute (ANSI) standard IT9.1-1989 covers film processing standards, and the International Standards Organization (ISO) 9660 specifications publication discusses the production of CD-ROMs which meet international technological standards. These standards should be followed when exercising either the microfilm or CD-ROM option.

ENDNOTES

1. DOE History Division, "US Department of Energy, Office of Environmental Restoration and Waste Management, Site History of the Fernald Environmental Management Project." January 1993.

2. National Lead Company of Ohio. "Capability Brochure," NLCO-950, March 1965.

3. National Lead Company of Ohio. "Employee Bulletin," November 19, 1981.

4. HAI conversation with Mike McCullough, Radiology Department, Sinai Hospital, Baltimore, MD, January 16, 1996.

5. HAI meeting with FERMCO Records Management, November 28, 1995.

6. General Record Schedule, number 1, item 21a(1), Transmittal No. 4, April 1992.

7. Ritzenthaler, Mary Lynn, Gerald J. Munoff, and Margery S. Long. *Archives & Manuscripts: Administration of Photographic Collections*. Chicago: Society of American Archivists, 1984. Chapters 1 and 5.

8. Image Permanence Institute, "Storage Guide for Acetate Film" (Rochester:Image Permanence Institute, 1993), 8-9.

9. *Hawley's Condensed Chemical Dictionary*, 12th ed. revised by Richard J. Lewis, Sr. (NY: Van Nostrand-Reinhold Company, 1993), 7.

10. Messier, Paul. "Preserving Your Collection of Film-Based Photographic Negatives." prepared for the Rocky Mountain Conservation Center, 1993.

HAI conversation with Mike McCullough, Radiology Department, Sinai Hospital, Baltimore, MD, January 16, 1996.

Mr. Messier's recommendation for gloves, goggles, and respirator pertain specifically to nitrate-based negatives, which produce nitric acid and other compounds which are definite health hazards. Mr. McCullough also recommends that eye protection and respirators be worn by those handling acetate-based and badly deteriorated film or working near it. Although dermal contact with the particles and acetic acid should not pose a health concern, HAI suggests also wearing gloves while working with the x-rays to prevent the transfer of oils and impurities on the hands to the film surface.

11. HAI conversation with Mary Ann Wallace, DOE Records Management, December 12, 1995.

12. Image Permanence Institute, "Storage Guide for Acetate Film" (Rochester:Image Permanence Institute, 1993), 11.

13. HAI conversation with Mike McCullough, Radiology Department, Sinai Hospital, Baltimore, MD, January 16, 1996.

14. History Associates Incorporated. *Planning Document for the NIOSH Records Management Center and Archives.* Prepared for the National Institute for Occupational Safety and Health, August 28, 1995. Appendix I, pp. 5-6.

15. HAI conversation with Tom Wright, Eastman Kodak, December 8 & 18, 1995.